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Sustainable energy development and environmental protection: Implication for selected states in West Africa

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ABSTRACT

The study exposed the energy situation of ECOWAS member states with particular focus on Nigeria, Niger Republic, Togo, Benin Republic and Ghana. It highlighted the various indices that represent the state of energy production and distribution and surveyed the renewable energy potential of the countries. The factors responsible for the energy poverty experienced by the countries were discussed and some implications of the energy state of the countries were exposed. It was found that although the countries have very good potential for renewable energy application for power generation, they were however limited by certain factors. These factors include a lack of or not enough robust national renewable energy resource measurements and assessments, and also lack of economic incentives to favour renewable energy technology development. Some policy suggestions that will promote the development and growth of sustainable energy in the countries were proposed.

Contents

1. Introduction

Energy is basically defined as the ability to do work [1]. It is a force multiplier that enhances man's ability to convert raw materials to useful products and also provide services [2,3]. Its consumption and utilisation determines the factors of increase or decrease in the population and also the gross domestic product (GDP) of a nation. This is because of its ability to drive industrialisation and provide infrastructure development. A lack of energy in an economy or its inadequacy can lead to social and economic poverty, under-development, unemployment, high level of illiteracy and increased migration [4]. It is reported that the performance of the various women right, literacy, and millennium development goals programmes, as well as

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the birth control policies, hinges strongly on the availability of modern energy [4].

Several people in the rural areas of developing countries and some poor nations around the world constantly lack access to modern energy supply. It is reported that about 1.5 billion people in developing countries lack access to electricity, and about 2.4 billion people use traditional biomass for cooking, heating, and other energy needs in an unsustainable manner [5,6]. Within the Sub-Saharan African countries, it is reported that although the region represents about 14% of the total population of developing countries, it accounts for almost 40% of population without access to electricity [6]. While still depending on biomass burning for energy, the environmental contribution of such a practice is negative and causes pollution and emission of harmful gases [7,8].

The global energy modules have over the years relied on sources which include fossil fuels and nuclear reactors. While these sources can produce sufficient energy for national consumption, their depleting nature places a limitation on their availability. The soaring cost of producing electricity from these sources is another discouraging factor for developing and developed nations. Worst of these is the emissions from them. The use of fossil fuels poses some major challenges to the environment, to humans, and national economies. Burning fossil fuels for energy releases greenhouse gases. These gases include carbon monoxide, carbon dioxide, water vapour and other deleterious compounds of nitrogen and sulphur which could be methane, nitrous oxides (NO_x) and sulphurous oxides (SO_x). These products of fossil fuels combustion are active gases that terribly affect the world's environment causing global warming and leading to climate change. Acid rain is another evil effect emanating from fossil fuel burning. It has corrosive tendencies on buildings, roofing materials and paints and also damages crops, forest, streams, lakes and rivers. Humans exposed to large volumes of methane, NO_x, and SO_x could develop respiratory infections. Nuclear waste, on the other hand, is strongly radioactive. It has a long life span of over a hundred years. It can be dangerous to human, animal and plant lives if the wastes are not properly stored in a way that the reactivity is discontinued [3,7–11].

Be it as it may, the challenge of providing adequate and sufficient amount of energy for the populace is a global issue. The depth of concern may vary from developed to underdeveloped nations, but the exercise of making energy scarcity a foregone issue is a major phenomenon around the world. Thus ways of adequately meeting the growing energy demand of the world are globally attractive. The over reliance on the conventional non-renewable energy sources is being discouraged internationally for the past three decades. This has led to debates and action plans from such events as the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC). More so, the intermittence, inadequacy, and depleting nature of these sources have made them unsustainable. Africa and indeed West Africa must brace up to the challenge. The focus of this study was therefore to critically review and analyse the progress that West Africa has made in sustainable energy development with particular focus on five countries – Nigeria, Ghana, Niger, Benin and Togo Republics. It highlights the energy scenarios of the selected countries and discusses the attendant environmental implications.

2. Energy scenario of some west African countries

The challenge to meet the demand of energy cuts across most of the African countries, especially members of the Economic Community of West African States (ECOWAS). In 2003, the report from the United States Energy Information Administration [12] puts the total electricity generation from all sources of all West African countries at 3550.2 MW (MW). Of this, Nigeria's share is the highest (about 50% of total), followed by Ghana (about 17% of total), Senegal (148.4 MW) and the least being Cape Verde. These values compare negatively with the region's total electricity consumption which was put at 3270 MW. Comparing countries' generation with consumption as shown in Table 1 revealed that West Africa is in a critical state of energy insufficiency. 92% of the total electricity produced is consumed with some nations needing importation to meet demand. Worthy of note is the fact that the energy consumed is far below that demanded. A report by UNDP-WHO [6] stated that, although energy access varies widely across developing countries, it is much lower in poorer developing nations. The report further stated that 79% of the population in the least developed countries lack access to electricity as compared to 74% in sub-Saharan Africa. Also, 56% of the population of developing nations depends on coal and traditional biomass for their cooking and other energy needs. The energy consumed by these people is not included within the consumption data. If such data had been captured, probably all the countries in Table 1 would have fell short. The present statistics suggests a similar trend. Thus, pointing to the fact that the current West Africa's energy systems need revisiting with the aim of developing adequate and suitable energy system which will be sustainable and environmental friendly.

Table 1 further reveals that, only two countries have reasonable reserve over consumption. All the other countries consumed between 80% and 95% of their total production. The first three countries and The Gambia need importation to cater for their energy needs because their consumption exceeds their production. Nigeria is the biggest producer followed by Ghana. These two

Table 1
West Africa electricity information in megawatts (MW) as at year 2003 [12].

S/N	Country	Production value (MW)	Consumption value (MW)	% Consumption over production
1	Benin	11.4	61.6	Importation
2	Togo	22.8	74.2	Importation
3	Niger	22.8	29.7	Importation
4	Nigeria	1780	1660	93
5	Ghana	616	580	94
6	Mali	91.3	86.8	95
7	Senegal	148	142	95
8	Guinea	91.3	82.2	90
9	Sierra Leon	34.2	27.4	80
10	Liberia	57.1	53.7	94
11	Burkina Faso	45.7	40.0	88
12	Cape Verde	0.0	4.6	Importation
13	Mauritania	22.8	19.4	85
14	Cote D'Ivoire	582	390	67
15	Guinea Bissau	11.4	5.7	50
16	The Gambia	11.4	14.8	Importation
	Total	**3550**	**3270**	**92**

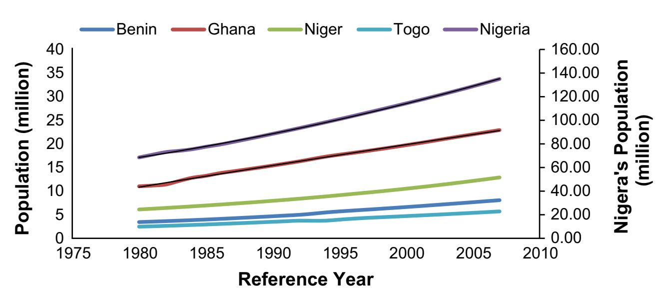


Fig. 1. Annual population estimates for the countries from 1980 [3].

nations, however, are still in critical energy shortages when consumption is placed beside population (see Fig. 1). With the population of Ghana and Nigeria in the year 2003 standing at about 21.11 million (average annual population growth rate of 2.76%) and 122.79 million (average annual population growth rate of 2.54%), respectively [13], the electricity availability per person derived from the ratio of total production to population is 255.8 kW-hour (kWh) and 127.0 kWh. The magnitudes are small when compared with other nations like Italy (4654.49 kWh/person) and United Arab Emirates (11,045.58 kWh/person). The population of these countries in 2003 was put around 58.03 million (average annual population growth rate of 0.11%) and 3.73 million (average annual population growth rate of 5.68%). Ever since the last two decades there have been various agitations and attempts by governments of these countries to improve their energy productions and supplies. One of such attempts is the development of the gas pipeline project which will run from the Niger Delta area of Nigeria to the boundaries of Ghana, Benin Republic and Togo. The project is still ongoing. The focus of this study is on the energy state of the first five countries of Table 1. Nigeria, Benin Republic, Togo, Ghana and Niger Republic are neighbouring countries in the West Africa sub-region (see Fig. 2). These countries, apart from Niger, are bordered to the south by the Atlantic Ocean and the gulf of guinea. They share similar climatic conditions with two distinct seasons of dry and wet (or rainy).

Currently, with a population of about 152 million, Nigeria produces about 207 kWh/person of electricty while Ghana with a population of about 25 million produces almost 327 kWh/person. The per capita consumption of electricity for each of the first five countries is shown in Fig. 3 [14].

Fig. 2 shows that the per capita electricity consumption (in W) for the countries range from 25.8 to 47.8 for Ghana, 12.5 to 16.9 for Nigeria, 9.5 to 18.6 for Togo, 4.8 to 9.9 for Benin Republic and 2.4 to 4.8 W for Niger Republic, respectively. This reveals that despite the fact that Nigeria increased electricity generation more than the other countries, within the period between 2000 and 2011, the demand far exceeded production. The low values of the per capita consumption also points to the fact that several citizens of these countries would have sought their electricity and other energy resources from other sources. These sources may include fossil fuel and biomass burning. For instance, Niger's energy consumption which is estimated at 13,956 GWh a year is made up of 91% fuelwood and agricultural residues [15]. This also further demonstrates that, environmental protection may not be realized effectively if the energy poverty of the West Africans and those of other developing countries are not resolved. It may also impinge on the debate against deforrestation.



Fig. 2. Map of west Africa showing the relative location of the referenced countries []. *Source*: d-maps.com

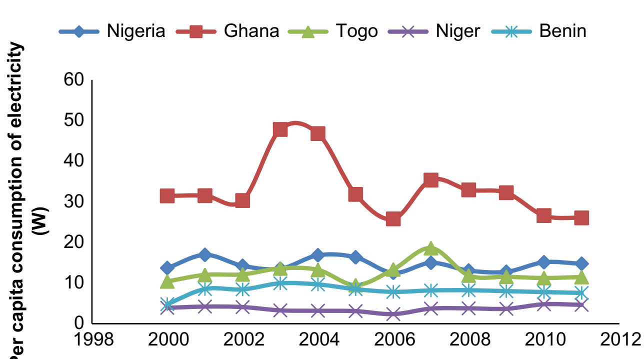


Fig. 3. Per capita consumption of electricity [4].

3. Environmental consideration of the energy poverty scenario of referenced countries

Figs. 4 and 5 give the magnitudes of carbon dioxide (CO_2) emissions from the consumption and flaring of fossil fuels and also from consumption of only petroleum [16,17]. The data excludes the unregulated burning of fuelwood and other traditional biomass which mostly takes place in rural areas.

Fig. 4 clearly demosntrates that Nigeria is the highest CO_2 emitter of the countries and indeed of the ECOWAS sub-region. This is particularly due majorly to the crude oil exploitation and refining in Nigeria. The country has not been able to achieve the zero flare plan of the Federal government. Today, the country still flares most of the associated natural gas because many of the oil fields lack the ability to prduce the gas. The deadline to implement its no-flare targets has always been postponed. The most recent date is set for December 2012. The proposed new gas-fired power plants that will help reduce gas flaring is still in progress and yet to be completed. Hence, the target achievement may take a while [18].

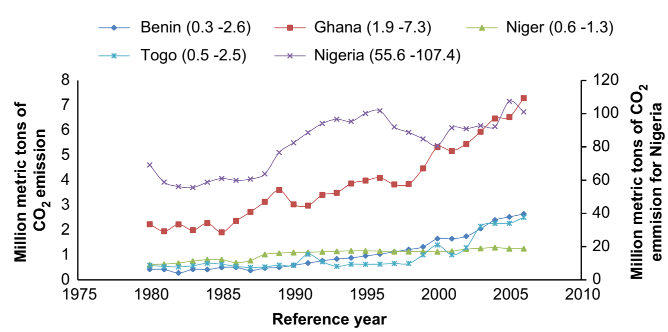


Fig. 4. CO_2 emission from the consumption and flaring of fossil fuels [6].

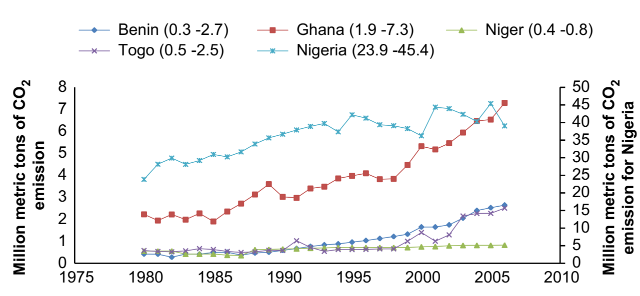


Fig. 5. CO_2 emission from the consumption of only petroleum [7].

Comparing Fig. 4 with Fig. 5 shows that apart from Nigeria and Niger, the CO_2 emission data for the scenarios of the two figures are the same. This invariably demonstrates that the fossil fuels consumed by these countries is mainly petroleum. Niger on the other hand, in addition, emits CO_2 from coal generated electricity to power its uranium mines. Nigeria emits between about 31.7 and 62.0 million metric tons of CO_2 from only petroleum consumption. Worthy of note is the fact that, the CO_2 emission data is made worse across the countries because of their energy poverty. Most of the citizens and industries, especially in Nigeria, rely on self-generated electricty from petroleum-fired machines for domestic and industrial needs. Further to this, if the statistics of emissions from biomass burning can be captured and collated, it may lead to doubling or more of the data as demonstrated by Figs. 4 and 5. Thus ways to improve the energy shortages of the ECOWAS countries cannot be overemphasised.

4. Energy systems of the referenced countries

Considering the various sources of national electrical energy generation by these countries revealed that production is wholly based on two major sources which are hydro and thermal. While these sources are capable of producing enormous energy, sole dependence on them have led to insufficient power production. This is because of the seasonal dependence of hydropower and the rising cost of natural gas. The cost of maintaining existing power plants and also developing additional capacity is another issue which comes to the fore. The majority of the power stations are operating below the installed capacities. For instance, Nigeria power sector operates below its estimated installed capacity. In 2004, the total installed capacity was 5.9 Giga-Watts (GW) while total electricity production was put at 19 billion kilo-Watt hour (bkWh) (or 2.17 GW). Of this, 18 bkWh (2.05 GW) was consumed with only 40% Nigerians, mostly urban dwellers having access to this energy [19,20]. Moreover, in 2008, the difference between installed capacity and production capacity amounted to 40.8% losses [21]. As at 2001, about 25% of the 774 local government areas of Nigeria were not connected to the national grid and presently, more than 70% of these areas are still not connected. Electricity access is put around 50–60% of total population [6,19], while the rural access to electricity in Nigeria is reportedly put at 26% in 2008 [6]. There has not been any major improvement in statistics ever since.

Ghana, on the other hand, has embarked on energy reforms in the last two decades. Its rural access rose from 16% to 25% between 1992 and 2001. In 2010, total electricity generation was 10232.11 GWh with total power transmission loss estimated at 4.0%. Also, by 2010 about 4813 communities were connected to the national grid, corresponding to 57.8% total coverage. These communities comprise all regional and district capitals leaving mainly rural areas [22]. Between 2006 and 2007, the nation's average rural access rate was about 60% [23]. As at November 2011, access to electricity is reported at 77.2% with urban areas having the larger share of 80% [24].

Niger and Benin Republics are two nations whose major energy needs are met by energy importation from neighbouring countries like Nigeria and Ghana. This is because, their total demand exceeds production. For instance, as at 2004 Benin Republic's total energy consumption was 25376.66 GWh while its per capita energy consumption was estimated at 9.7 W. In the same year, national electrification rate was estimated at 23.4% while the rural access rate was 2.0% [25]. The population of Benin Republic in 2004 is about 7.4 million. With this electricity scenario, Benin's total energy requirement would have focused on biomass resources. In Niger, 87% of the total electrical energy is imported from Nigeria while local generation from thermal and coal fired turbines makes up the remaining 13%. The ratio of electrical energy to total energy in Niger's energy mix is estimated to be 2% and only 5% of the population has access to electricity. By 2008, the access rate improved to 9.3% [15,26,27].

Togo, on the other hand, receives about 80% of her electricity in the form of hydroelectric power from the Akosombo Dam in Ghana. There is also a hydroelectric station at Kpimé, near Kpalimé, and another 65-Megawatts Mono River hydroelectric plant, near Atakpamé, which began operating in 1987. The facility has an average output of 150 million kWh, enough to meet 25% of the combined demand of Togo and the joint project partner Benin Republic. However, only about 17% of Togo citizens have access to modern electricity supply as at year 2005. Also, in 2005, the nation consumed 576,000 MWh of electricity, out of which 84.4% were imported from Ghana [28]. Currently Togo's modern energy is largely dependent on importation from neighbouring countries.

Going by the aforementioned and with the reality of the projection that demand for electricity in West Africa will increase by about 5 per cent annually through 2026 [28], the state of energy in these countries needs urgent address. The question then is, are there prospects for increased energy production that would meet global environmental standards and satisfy growing population needs? One major solution lies in the use of Renewable Energy (RE) sources for power and other energy production. These sources contain sustained opportunity for meeting global energy needs. They are environmentally friendly, enormously available, cheap, easily accessible, naturally applicable, non-depleting, non-toxic source of valuable and usable energy [29]. Another advantage of RE is its ability to be operated as a standalone facility. It has the potential of providing independent energy for rural community utilisation. It can also be deployed for agriculture and other light electrical purposes. Moreover, it has been recognised through satellite data provided by the solar and wind energy resource assessment programme of the United Nations Environment Programme (UNEP), that West Africa region is very rich in renewable energy resources. These resources, especially solar and wind energy are abundant with enough production capacity to serve the rest of the sub-Saharan region. It is also stated that the amount of available solar and wind within this region is in large excess of current and projected demands of all ECOWAS [30]. The concentration then may be to have energy diversification, to include new-renewable energy to the running energy mix of the countries.

5. Sustainable energy potentials of the countries

Nigeria, Ghana, Togo, Benin and Niger Republics, each have rich supply of these abundant wind and solar resources with other renewable reserves in varying capacities.

5.1. Nigeria

Nigeria has wind speed variations depending on the geo-political zones. Average wind speed in the north is within the range 4.0–8.5 m/s and in the south between about 2.9 and 4.0 m/s at 10 m height [31,32]. The mountainous regions of the north and the coastal areas of the south have the potential of average wind speeds of above 8.5 m/s. Solar irradiation is put at an average of 5.5 kWh m^{-2} day^{-1}. The estimated combination of large and small scale hydropower potential is put at over 13184.2 MW of which the small scale capacity is estimated to be at least 994.2 MW. Presently, the nation operates about 30 MW of small hydropower and less than 2000 MW of large hydropower schemes located across the country [33,34]. Also, opportunities for biomass energy cultivation, majorly from large fuelwood, agricultural residues,

industrial and domestic wastes, exist within the country. It is estimated that Nigeria has over 200 MWh of biomass resources [20,33,34]. These biomass resources if properly developed can be a rich source of biogas and biofuels. For instance, Jatropha is a plant which easily grows in Nigeria. It is not edible but can be used for biodiesel production [35,36,37].

5.2. Benin republic

Benin Republic boasts of rich supplies of solar energy resources with annual sunshine hours of about 2500 h and solar irradiation of 5.4 kWh m^{-2} day^{-1}. Average wind speed of 5.0–6.0 m/s at 50 m height is economically viable for wind power production. Also, the nation has potential capacity of biomass production of about 5266.15×10^6 kg of agricultural residues, with high capacity for hydropower [25,35].

5.3. Togo

The country has no natural gas or other fossil fuel deposit in commercial quantity. Its energy resources are derived from imported hydropower and petroleum. 80% of the nation's electricity is from hydropower. Although, Togo does not utilise any renewable energy resource, the country has enormous potential for new renewable energy especially from wind and solar. The wind speed resource is estimated to be between 3.0 and 10.0 m/s at 10 m height with higher potentials in north, north-central and southern parts. Areas around the Ghana–Togo border have been noted to have average wind speeds in the neighbourhood of 9.0 m/s [38,39]. On the Atlantic coast, average wind speed of about 6.0 m/s is possible year-round.

5.4. Ghana

Apart from Nigeria, Ghana is the next power house in terms of quantity of electrical energy produced per annum. The recent discovery of crude oil in commercial quantity is also boosting Ghana's drive towards energy sufficiency. Utilisation of renewable energy resources is rapidly growing in Ghana. Currently most of the electricity generation in the country is from hydropower. Solar energy application has also gained acceptance in the country. Research and development around renewable energy technology is rapidly growing. Viable RE technologies identified within the country include wind power, off-grid solar-rural electricity, solar heating, biodiesel, small and mini hydropower schemes. Along the coast of Ghana, wind speeds of 3.0–9.0 m/s have been recorded at reasonable heights. On the average, monthly mean wind speeds of about 6.8 m/s at 50 m height is possible. The country is presently preparing to have its first wind power project running. Exploitable wind potential is estimated to be between 300 and 400 MW [25].

Biomass resources in Ghana are considered to be the dominant energy resource in terms of endowment and consumption, supplying about 60% of the country's total energy [40]. The country is about beginning to exploit grid connected solar electricity full scale with different pilot projects ongoing. The monthly average solar irradiation is estimated at between 4.4 and 5.6 kWh m^{-2} day^{-1} and sunshine duration of between 1800 and 3000 h per annum [25].

5.5. Niger republic

Niger Republic like its neighbours equally boasts of abundance of renewable energy resources. The country has good potential for biogas and biodiesel production while the wind speed regime is high in the far north and moderate or low in the south. Average wind speeds of 5.0 m/s is available in the north and 2.5 m/s in the south at 10 m height [27,28,41]. The potential for solar energy technology is also as can be compared with other countries in the region. The country's solar resource potential is averaged between 5.0 and 7.0 kWh m^{-2} day^{-1} with about 7–10 h of daily sunshine [41]. Also, as a result of the river Niger which runs through the nation, it has huge potential to tap the resources for hydropower generation. It is estimated that the country has hydropower capacity of about 274 MW along the river with an average output of about 1156 GWh [27,28,41].

Thus, to build sustainable energy and at the same time protect the environment, each of the countries would need to develop new energy modules which will basically depend on their RE resources. In doing this there are implications which the process poses. These implications include overcoming attendant challenges and embracing new development models which will pull the nations out of their energy crises.

6. Implications of the progress of sustainable energy development and the level of adoption

Globally the shift from conventional energy sources of fossil fuels and nuclear reactors have gained improved attention. Various conventions and debates have also agitated for the protection of the environment through energy diversification to include the renewable energy resources. Nigeria, Ghana, Benin Republic, Togo and Niger Republics have identified renewable energy potentials for power generation. The development and utilisation of these resources in some of these countries have however been hindered by the lack of adequate measurements and assessment studies to ascertain its viability [42]. This probably has hindered local and international renewable energy investors from embarking on technologies to promote utilisation of RE technologies in the countries [43]. In harnessing the potentials of renewable energy resources in a country, the first step of resource assessment of as many sites as possible cannot be overemphasised. The results from such studies will provide information on the resource distribution across the terrains of the country.

Based on this, Nigeria and Ghana have made some progress. For instance, there are some researches that have reported on the assessment of wind energy resource availability and distribution in Nigeria [30,42,44–52]. On solar energy distribution, majority of the available reports are on modelling [53–58]. This is because most of the meteorological stations spread across the country do not measure solar radiation incident on a particular surface. Also, only very few assessment reports exist on the potentials of other renewable energy resources available in the country, such as biomass-to-biofuels/biogas [59–64]. None exist on the geothermal resources. There are still some Small Hydro Power (SHP) potential sites scattered around the country that have not been assessed. However despite the fact that some potential have been identified and assessed, the country is yet to begin rigorous adoption of the renewable resources for power generation. Apart from large hydropower, there is no other grid connected RE project ongoing in the country. What is available as yet is the adoption of solar energy for lighting, solar thermal and solar drying.

Ghana, on the other hand, has made more improvements in tapping the solar energy resources more than any other RE sources (apart from hydro). On the level of assessments of the other RE resources, the country has more to do. Very few reports exist on biomass resource assessment and biomass-to-biofuel/biogas potential in the country [61]. The question as to whether there are other renewable energy resources apart from the aforementioned cannot be answered as yet. Benin Republic, Togo and Niger Republic have more to do in exposing information regarding the availability, potential and distribution of their renewable energy resources. There is a dearth of information on the potential of the

available RE for power generation in the three countries. The level of awareness of these resources in the countries is low and needs great improvement. There is however mesoscale data that gives the average distribution of each of the resources across the five countries. Although mesoscale data are useful for policy generation, having site specific data for direct application is also essential. Thus in order to attract both local and foreign investors, there is a need to have as many site specific information as can be possible. Such reports must be internationalised.

Apart from all the aforementioned resources, none of the countries have exploited or about to exploit the available resources of their ocean, tidal and wave power potential despite their location to the Atlantic. The potential of offshore resources for wind power generation is high, but no information is available on the resource assessments across the countries. Furthermore, the governments as well as the private sector may need to form partnership in order to fund research and development towards the development of Renewable Energy Technologies (RET) across the countries. This will improve the knowledge base of indigenous researchers. Also, maintenance capacity within the countries will be built, thus, encouraging industries to embrace them for their production facilities. Naturalising RET is easy when research and development are built locally to service the facilities. The countries that have research/assessment results on the available RE resources may also need to pursue the development of the resources to match with the reports. The governments may in addition embrace the technology of water recycling at the hydropower dams to eliminate the recurrent problems of water shortages.

7. Policy initiatives that can promote sustainable energy development in the countries

To promote the development of sustainable energy and at the same time protect the environment require deliberate efforts. Such efforts may include having a proper legislation that supports RET development in the countries. The countries may also need to provide market incentives to favour the growth and adoption of RET. Such an initiative may include granting low/interest free loans for financing RET, provision of adequate subsidies to support the sale of renewable energy and granting tax holidays to willing private RET marketers. Some other relevant policy initiatives could also include establishing strong institutional leadership for RET advancement [30,47]. Also, there should be deliberate attempt to grant subsidy to support the deployment of RET, especially in rural and peri-urban areas [65]. This subsidy should be systematised in such a way that it will boost investor confidence for long term capital investment and ameliorate the likely response to market risks and future market dynamics [65]. The major ill to RET adoption for rural electrification is the huge initial capital involvement. This huge financial investment and the unwillingness of the rural poor to pay such a high price for modern energy have made the RET application to rural areas economically unfeasible and thereby unsustainable for the governments [66]. However, it is thought that if the governments will subsidise the cost of electricity to rural dwellers, especially those in very poor communities, the long term benefits of macroeconomic development will be achieved. In addition, the countries may need to integrate wind and other RETs into their rural development plan [47]. It will also be encouraging if the governments of these countries form a regional collaboration towards enhancing renewable energy development in their countries by providing technical supports to each other in areas where there is local specialisation. They may also embrace the version of the Kyoto protocol as applied by the European Union countries' framework accord of eliminating greenhouse gas emission level of 1990 by 20% and make renewable energy account for 20% of total energy consumption by year 2020.

8. Socio-economic, political and cultural implications of sustainable energy growth and development in the selected countries

Shortages in modern energy supply affect not only the socio-economic well being of a state but also have implications on the socio-cultural and political stability of the state. A country without adequate supply of electricity for instance prompts many of the industries to rely on alternative sources of diesel and petrol generators [67,68]. Thus a lack of energy in an economy or its inadequacy may lead to social and economic poverty, under-development, unemployment and underutilisation of rural human resources [67,69]. Other effects can also include economic stagnation, underperformance of industries and industrial sectors, low turnover, high level of illiteracy, costly products and increased migration [67–69]. For instance, Okpala [70] reported that although Nigeria's population density is high, it is however not equally distributed. It is the highest in the south and southwest urban areas and the lowest in the northeast. This is because the southern part is regarded as the economic hub of the nation. Further to this, the report also stated that rural–urban migration is growing due to the dual nature of the nation's economy. This is based on the fact that in the urban areas, the standard of living is high while in rural areas, a subsistence economy predominates. Similar trend is reported for Ghana [71], Togo [72], Benin [73] and Niger [74] Republics. People in such rural communities, especially the very poor communities, lack access to modern energy sources and rely on unsustainable means for heating and cooking. One common feature of citizens of rural communities in developing countries, especially those of sub-Saharan Africa, is the lack of access to information technology, good health care facilities, quality education etc. This is because of the lack of access to modern energy. However, energy has been reported to be an essential ingredient to development and its consumption is regarded as a useful indicator of the degree of well-being of a community [75]. One way to arrest this is for the governments to stress rural development through provision of social and economic amenities. These facilities will necessarily include modern power supply, achievable through adoption of RE into the rural development plan where grid extension is not economically feasible [47]. More so, the progress of the various women right programmes, literacy programmes, birth control policies and the millennium development goals programmes may be affected where there is lack of/or inadequacy of modern energy supply [76].

Moreover, adoption of RE in the rural development plan of a country has the direct effect of enhancing the economy of rural communities and also implies positively on the economic growth of the nation [69]. Due to the fact that several rural communities in the countries are not grid connected for electricity, distributed generation offers the least cost effective option [77]. This will reduce or eliminate the dependence on kerosene lighting, fossil fuel and traditional biomass burning [69]. It will also reduce the health risks associated with emissions from such unsustainable energy sources.

On a national scale, the adoption and development of RET leads to employment, increased internally generated revenue in terms of taxes associated with modern energy use, income and business taxes, value added tax etc. [65]. Other benefits include promotion of small and medium scale enterprises, reduction of emissions that are injurious to humans and the environment.

9. Conclusion

Sustainable energy planning and development is a major national task that cannot be left for the governments. It requires cooperation from private sectors, governments and field/research professionals. The governments on the one hand may need to build infrastructure, provide enabling RE business environment, and provide economic and other motivating incentives. The private sectors and field/research professionals, on the other hand, may seek for ways of partnering with governments to develop capacities and fund research and projects to promote RE. The majority of the rural communities without access to modern energy can be aided via the adoption and incorporation of RE into the rural development policy of the countries. The advantages of deploying RET as a standalone facility is a major benefit which can be employed for rural communities.

The governments may also need to build more measuring stations/sites, spread across the geopolitical zones of the nations in order to have site-specific data for direct viability assessment. This will, in addition, provide information on the resource profiles and distribution across the terrains of the countries. Public education about the advantages of RE resources may also be required across the countries. More so, countries that are near to the ocean can take advantage of their location by developing avenues for tapping offshore resources for power generation.

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